# Verifying DART Systems (DART)

Presentation to CERDEC
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# Report Documentation Page

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# Driving Vision

DARTs coordinate physical agents in an uncertain and changing physical world.

- Coordination – physical agents
- Timeliness – safety critical
- Resource constrained - UAVs
- Sensor rich – sensing physical world
- Intimate cyber physical interactions
- Automated adaptation to physical context and rational adversaries
- Computationally complex decisions

Coordination, adaptation, and uncertainty pose key challenges for assuring safety and mission critical behavior of distributed cyber-physical systems.

The DART project uses develops and packages sound techniques and tools for engineering high-assurance distributed CPS.


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# DART Assurance Today

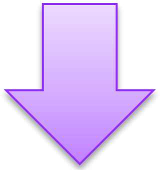
Currently validated via testing

- Low coverage, late in development

Rigorous & exhaustive analysis provides higher assurance

- Non-compositional V&V does not scale
- Probabilistic & deterministic requirements

Goal: Develop new theories, analyses and tools to engineer high-assurance DARTs with evidence of correctness

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# DART in a Nutshell

1. Enables compositional and requirement specific verification

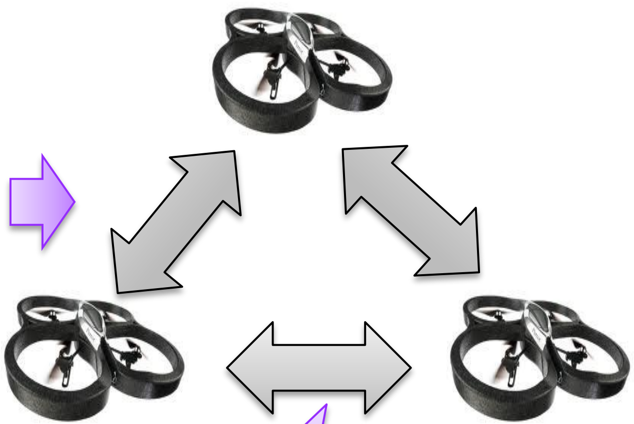
2. Use proactive self-adaptation and mixed criticality to cope with uncertainty and changing context

1. ZSRM Schedulability (Timing)

2. Software Model Checking (Functional)

3. Statistical Model Checking (Probabilistic)

**System + Requirements (AADL + DSL)** → **Verification** → **Code Generation** →



1. Middleware for communication

2. Scheduler for timing contracts

3. Monitor for functional contracts

Demonstrate on DoD-relevant model problem (DART prototype)

- Engaged stakeholders
- Technical and operational validity



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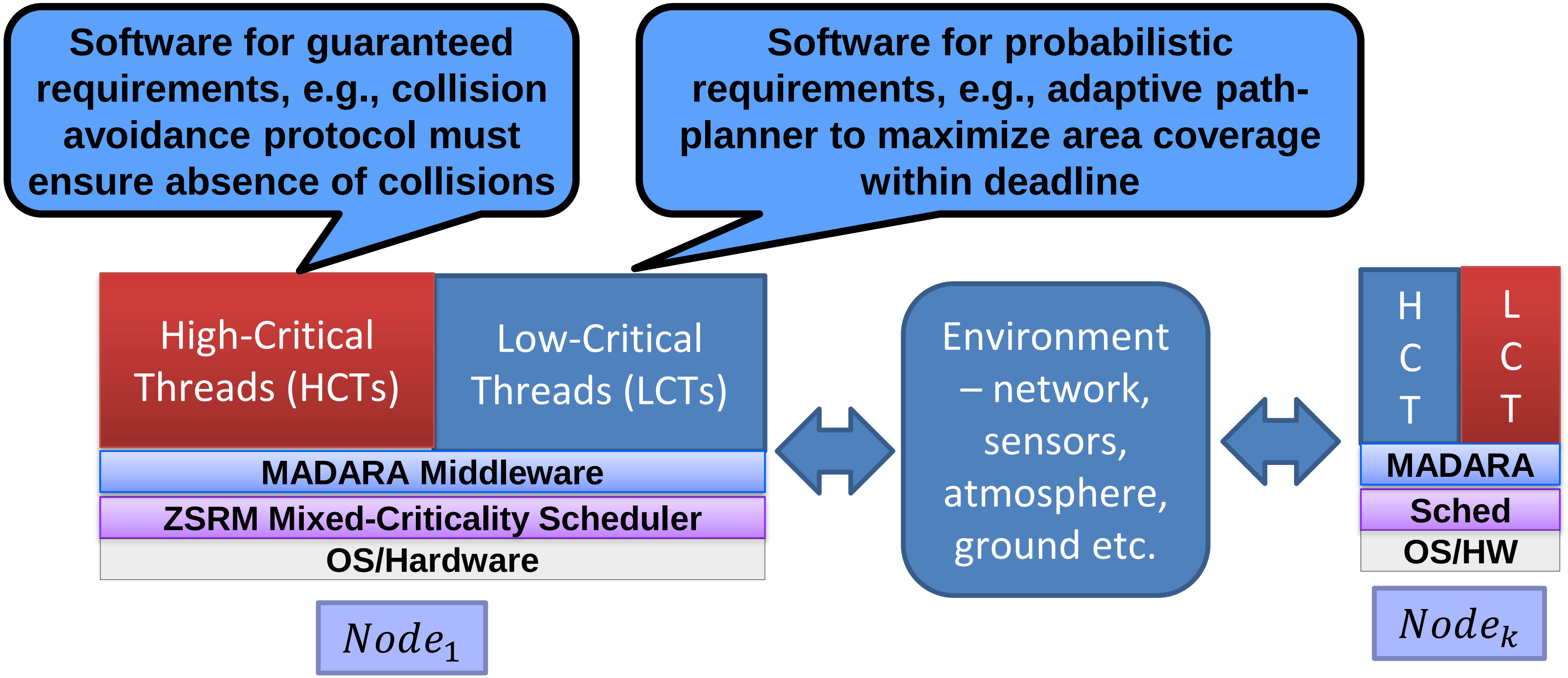
# DART High-Level Architecture




**Research Thrusts**

- **Proactive Self-Adaptation**
- **Statistical Model Checking**
- **Real-Time Schedulability**
- **Functional Verification**

**Validation Thrusts**

- **Model Problem**
- **Workbench**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# Roadmap & Foundations

| Thrust Area | Jan | Apr | Jul | Oct |
|---|---|---|---|---|
| Proactive Self-Adaptation | Latency-aware Self-Adaptation | CMU/SCS FY14 | | Disaggregation, Machine-learning |
| Verification | | | | |
| Real-Time Schedulability | ZSRM scheduler integrated with DART workbench | HCCPS FY12-FY14 | | Mixed-criticality among multi-agents & end-to-end OR with Input/Output |
| Functional Verification | Bounded Model Checking of Synchronous Software | HCCPS FY12-FY14 | | Unbounded Model Checking of Asynchronous Software |
| Statistical Model Checking | Crude Monte-Carlo based SMC, applied to simple examples | AFOSR FY14 | | Heterogeneous Fault Regions and Systems with Non-determinism, HPC Simulation |
| Workbench | Preliminary version of DSL, Code generation, ZSRM, CBMC, V-REP simulation, simple examples | MCDA FY14 | | Completed DSL, model problem, ODroid Code Generation, AADL/OSATE, Verification Tools |
| Coordination (ELASTIC) | Synchronous, multi-agent | GAMS FY14 | | Asynchronous, multi-agent |


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# Simple Model Problem: Coordinated Protection


**Guaranteed Properties**

No collision

**Best Effort**

Defensive perimeter

Resource conservation (e.g., fewest moves)

Adaptation w/ Uncertainty (next step)

Lose of a Protector

Lose of a Leader (new election)

Directional threats (shield formation vs. perimeter formation)

**Fleet's Initial State**

**Assumptions**

*2D Universe (X by Y matrix)*

Perfect communications between agents

Perfect localization for each agent

11 nodes

- $N_0$ is the leader
- $N_1 - N_{10}$ are the protectors

**Operation**

$N_0$ moves from $(x, y) \rightarrow (x', y')$

$N_1 - N_{10}$ move to maintain defensive perimeter


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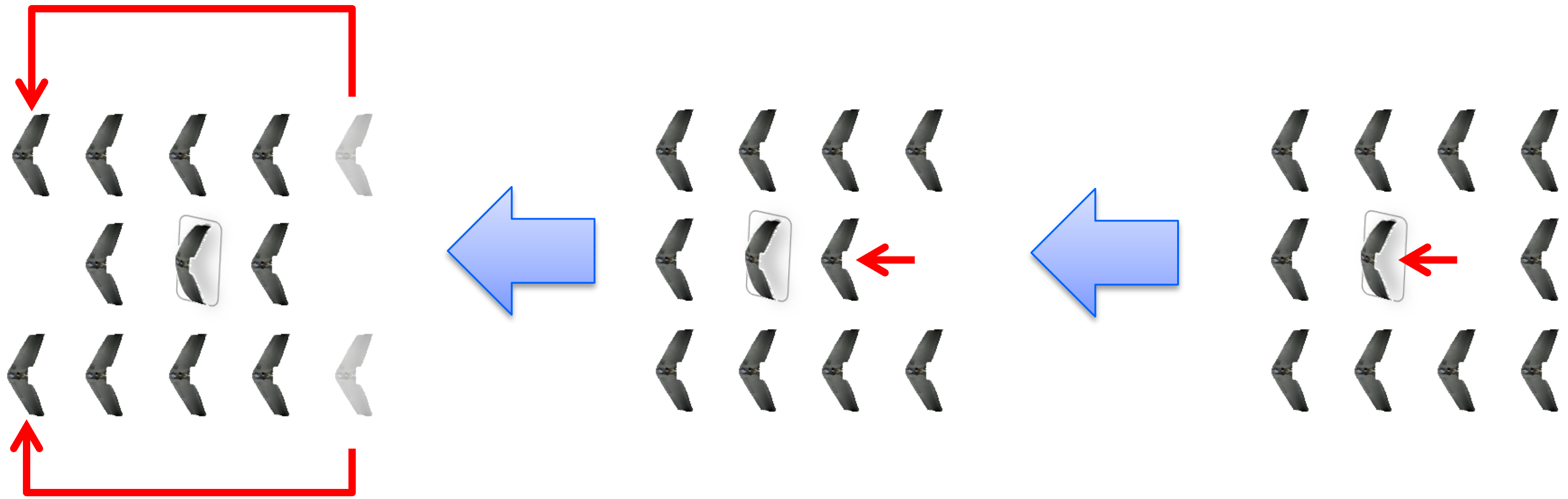
# Fleet Operation: Defensive Posture



**Free guard UAVs move around to front, simultaneously**

**Rear guard closes gap, leaving two free guard UAVs**

**$N_0$ moves from $(x, y) \rightarrow (x', y')$**

Coordination needed at each step to avoid collision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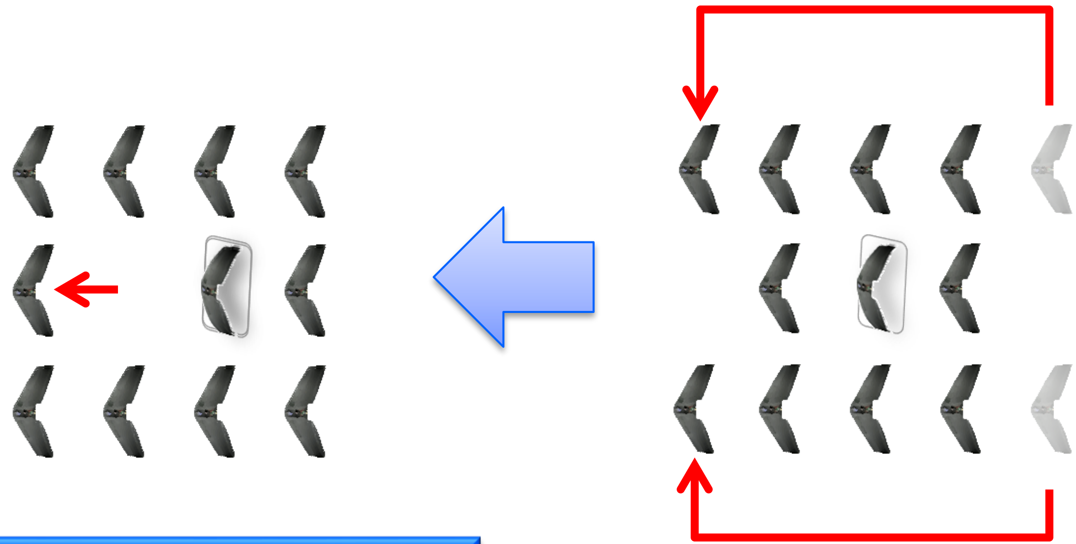
# Fleet Operation: Defensive Posture



Front guard UAV makes space for $N_0$ to move forward

Free guard UAVs move around to front, simultaneously

Coordination needed at each step to avoid collision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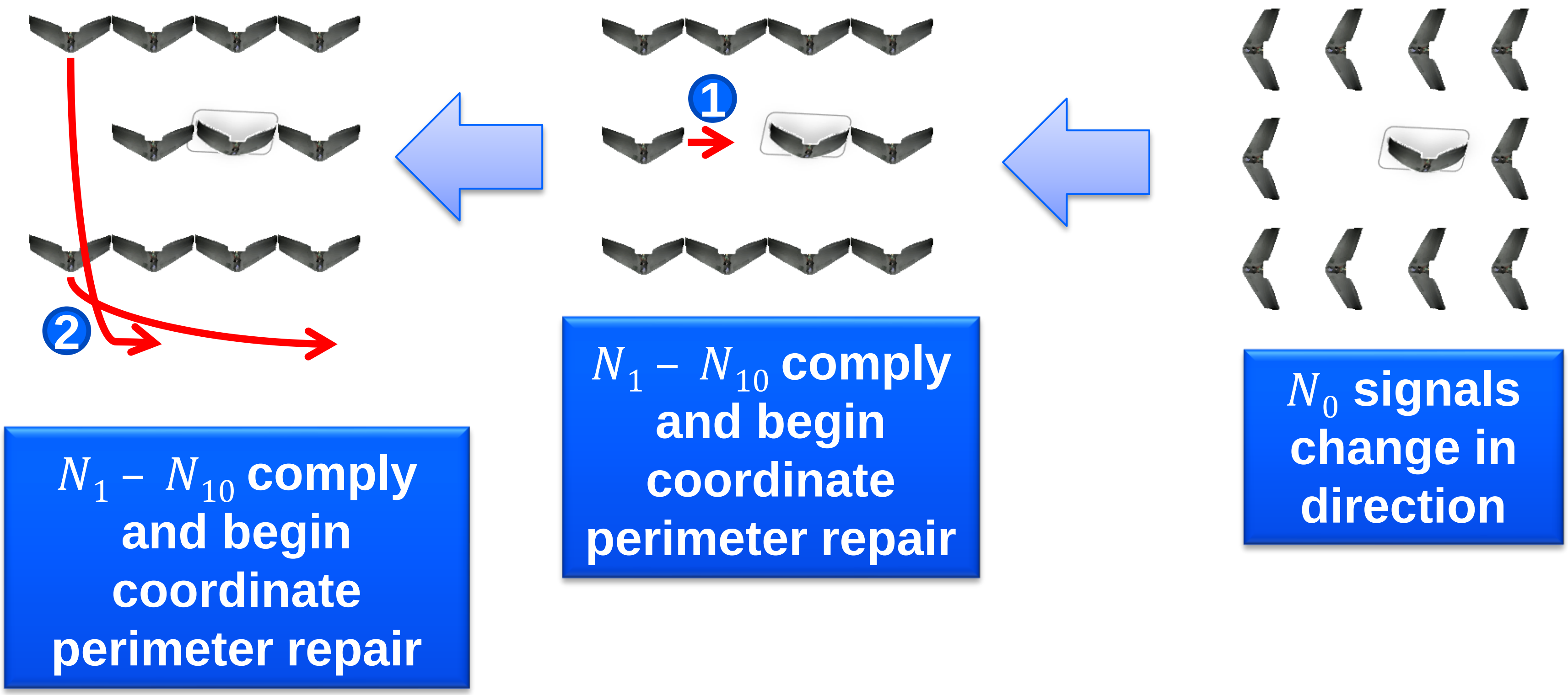
# Fleet Operation: Defensive Posture




Coordination needed at each step to avoid collision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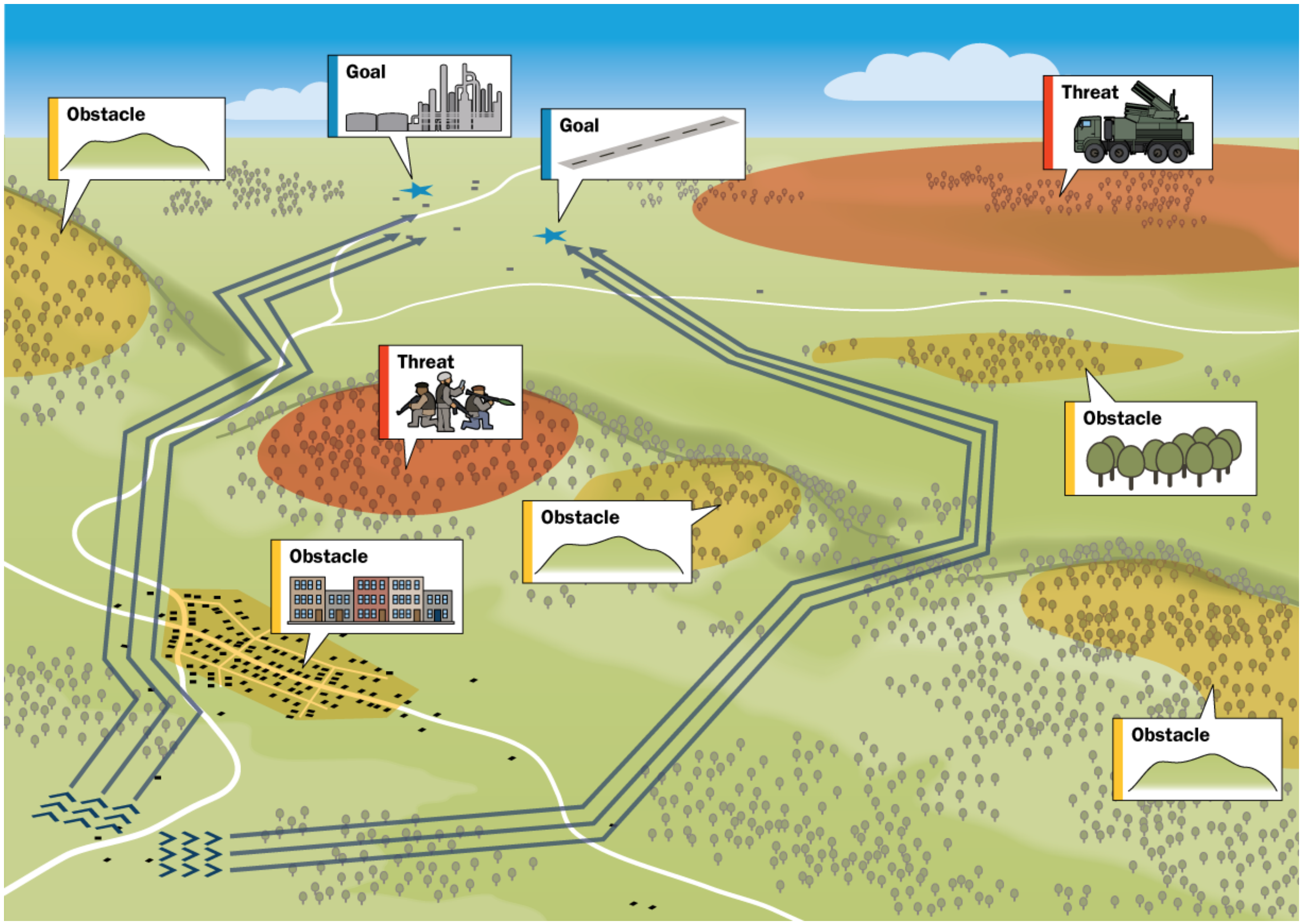
# Broader Model Problem




Mission assurance

- Goals
- Objectives

Resiliency

- Design time Verification
  - Guaranteed behavior
  - Best-effort behavior
- Runtime Assurance
  - Critical Timing behavior
  - Coordination
  - Adaptation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# QUESTIONS?

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# Contact Information Slide Format

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